dummy

Student Group

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Exercise E1 Machine-Vision Strobe: Capacitor Charging and Safe Discharge

charged, and must be safely discharged before maintenance.

Solution

Data: \begin{align*} C &= 1~{\rm \mu F} \\ W &= 0.1~{\rm J} \\ I_{\rm max} &= 100~{\rm

Assume the DC charging source is adjusted to the required final capacitor voltage.

1. What voltage must be present across the capacitor so that it stores the required energy?

\end{align*} A practical standard value would be about $4.7~{\rm k\Omega}$.

\begin{align*} U_0 &= 447.2~{\rm V} \\ RC &= 4.47~{\rm ms} \end{align*}

\begin{align*} W(t) &= \frac{1}{2} C u_C^2(t) \end{align*}

Initial and final values:

447.2~{\rm V} \end{align*}

exponentially.

\end{align*}

\begin{align*} W_0 &= 0.1~{\rm J} \end{align*}

With

After full discharge, the capacitor energy is zero, so the entire initial energy is converted into heat in the resistor:

\end{align*}

\begin{align*} W_R &= W_0 = 0.1~{\rm J} \end{align*}

we get

In a real design, the resistor must therefore be checked for pulse-load capability.

\begin{align*} t &= \frac{10~{\rm s}}{2}\ln(2) \approx 3.47~{\rm s} \end{align*}

The voltage at this instant is

\begin{align*} u_C &= U_0 \cdot \frac{1}{\sqrt{2}} = \frac{447.2~{\rm V}}{\sqrt{2}} \approx 316.2~{\rm V} \end{align*}

Exercise E2 Industrial Sensor Interface: Buffered Measurement Node

stable voltage for a short measurement cycle. At first, the measurement electronics are disconnected. Once the capacitor is fully charged, a switch closes and the measurement load is connected.

Solution

Data: \begin{align*} U &= 12~{\rm V} \\ R_1 &= 2~{\rm k\Omega} \\ R_2 &= 10~{\rm k\Omega} ... \end{align*}

[illegible]

So the load voltage starts at $10~{\rm V}$ and decays exponentially to $5~{\rm V}$.

\begin{align*} U_C(\infty) &= U \cdot \frac{R_2}{R_1 + R_2} \\ &= 12~{\rm V} \cdot \frac{10~{\rm k\Omega}}{2~{\rm k\Omega} + 10~{\rm k\Omega}} \\ &= 12~{\rm V} \cdot \frac{10}{12} \\ &= 10~{\rm V} \end{align*}

In practice, the capacitor is considered fully charged after about $5\tau_1$:

\begin{align*} t_{\rm charge} &\approx 5\tau_1 = 5 \cdot 10~{\rm ms} = 50~{\rm ms} \end{align*}

Exercise E3 Hall-Sensor Test Bench: Air-Core Calibration Coil

[illegible] ...magnetic field. An air-core design is chosen because it avoids hysteresis and remanence effects of iron cores. The coil is wound as a short, single-layer cylindrical coil.

Solution

Data: \begin{align*} l &= 22~{\rm mm} \\ d &= 20~{\rm mm} \\ d_{\rm Cu} &= 0.8~{\rm mm} ... \end{align*}

[illegible]

A useful engineering rule is: after about 5τ, the current has reached more than 99%...

\begin{align*} i(t) &= \left(1-e^{-t/\tau}\right) \end{align*}

\begin{align*} \tau = \frac{L}{R} \end{align*}

Mathematically, the exact final value is reached only after infinite time.

So the sketch starts at $0~\rm A$, rises steeply at first, and then approaches $1~\rm A$ asymptotically.

First, determine the copper cross-sectional area:

$$\begin{align*} A_{\rm Cu} &= \frac{\pi}{4} d_{\rm Cu}^2 = \frac{\pi}{4}(0.8~{\rm mm})^2 \\ &= 0.503~{\rm mm^2} \end{align*}$$

The mean length of one turn is approximately the circumference:

$$\begin{align*} l_{\rm turn} &\approx \pi d = \pi \cdot 20~{\rm mm} = 62.83~{\rm mm} \end{align*}$$

Thus, the total wire length is

$$\begin{align*} l_{\rm Cu} &= N \cdot l_{\rm turn} = 25 \cdot 62.83~{\rm mm} \\ &= 1570.8~{\rm mm} = 1.571~{\rm m} \end{align*}$$

Now calculate the resistance:

$$\begin{align*} R &= \rho_{\rm Cu}\frac{l_{\rm Cu}}{A_{\rm Cu}} \\ &= 0.0178~{\rm \Omega\,mm^2/m}\cdot\frac{1.571~{\rm m}}{0.503~{\rm mm^2}} \\ &\approx 0.0556~{\rm \Omega} \end{align*}$$